



THE CITY OF SAN DIEGO  
**MANAGER'S REPORT**

DATE ISSUED: January 21, 2005 REPORT NO. 05-024  
ATTENTION: Natural Resources and Culture Committee  
Agenda of January 26, 2005  
SUBJECT: Water Tank Selection Comparison: Steel versus Prestressed Concrete

SUMMARY

THIS IS AN INFORMATION ITEM ONLY. NO ACTION IS REQUIRED ON THE PART OF THE COMMITTEE OR THE CITY COUNCIL.

BACKGROUND

During the Council action to approve the award of a construction contract for the Black Mountain Road Recycled Water Tank Project, Council requested an informational item (report) be prepared by Engineering and CIP Management Division comparing a steel tank versus a prestressed concrete tank.

This report provides the basic information regarding storage tanks of common size used in the water distribution system for the City of San Diego.

The water utility industry has wrestled with this matter for many years. For most utilities, it comes down to a matter of preference, local vendor support, and specific site conditions.

## DISCUSSION

The Water Department has a large variety of water storage tanks throughout its distribution system ranging from 0.1 to 35 million gallons (MG)<sup>1</sup>. There are both buried (either fully or partially) and above grade facilities. Of the buried facilities, none are constructed of welded steel plate (WSP) due to the resulting aggressive corrosion degradation and steel's ductility. These facilities are either reinforced (cast-in-place) concrete (RC) or pre-stressed concrete (PSC) to withstand the compressive forces of the soil in addition to the expansive forces of the water. Focusing our attention then on the above-grade comparisons of WSP and PSC water storage facilities, these reservoirs are generally circular to minimize construction cost per gallon and to provide enhanced structural rigidity and seismic resistance. They are typically located at a high point in the service area (e.g. top of a hill) and are often visible from a significant distance. Their visibility requires non-technical community input regarding exterior coating colors and/or landscaping requirements to screen the facility from view. These factors always play a part in the selection process for a new facility.

Without exception, the smallest above grade storage tanks are of WSP construction and the largest are PSC. This arrangement is consistent throughout the water utility industry including the Water Department. The larger storage facilities are also typically associated with water treatment and transmission facilities (clearwells) rather than distribution systems (tanks & reservoirs). The Water Department currently has 7 WSP facilities with a total potable water storage capacity of 14.9 MG and approximately 240 MG of potable water storage capacity in 21 concrete facilities including PSC, reinforced concrete, and concrete lined (Attachment 1). Currently, the largest WSP reservoir in the country is located in Austin, TX<sup>2</sup>, the 34 MG Martin Hill Reservoir. The Water Department's 35 MG Earl Thomas Reservoir is the largest PSC reservoir in the world<sup>3</sup>. This report shall focus on the common tank sizes found in water distribution systems.

Typically the constructed capital cost is the overwhelming factor in the selection process for a storage tank. The distribution of WSP tanks in smaller sizes, less than 1 MG, and PSC reservoirs in larger sizes, greater than 10 MG, reflects this distribution. However, the constructed capital cost should not be the basis by which a facility is selected. The Present Value or life-cycle cost is the preferred economic analysis to compare different conditions and scenarios in an engineering environment. When performing a life-cycle cost analysis, there is a size range that provides competitive Present Value costs for tanks constructed of either material. This range, 1-5 MG, is

<b>TABLE 1</b>		
Present Value - Life-Cycle Costs (Nearest \$1,000)		
	Steel	Prestressed Conc.
1 MG	\$1,125,000	\$1,100,000
3 MG	\$2,328,000	\$2,135,000
5 MG	\$3,630,000	\$2,990,000
10MG	\$5,804,000	\$4,715,000

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1 The City of San Diego Water Department 2003 Data Manual lists 46 tanks and reservoirs. Some of the smallest at 6000 to 16400 gallons are actually welded steel hydropneumatic tanks and fall into a different classification than the tanks and reservoirs discussed in this document.

2 <http://www.ci.austin.tx.us/water/demandplan.htm>; <http://www.kleinfelder.com/news/Trinity%20Tank.html>

3 <http://www.dyk.com/AboutUs/Alvarado.html>

illustrated in Table 1 and in Attachment 2.

### LIFE CYCLE COSTS

The life-cycle cost or the cost to build, maintain, and operate a facility should be considered and compared to properly select a reservoir type. In a life-cycle cost analysis, basic assumptions are made regarding the intended use of the facility and how long the facility shall be used. These assumptions can be as sophisticated as a complete asset management plan or by using professional judgment and experience. This often makes an apples-to-apples comparison between materially different facilities a challenge. When calculating life-cycle costs, assumptions as to the service life, inflation rate, interest rate, and maintenance period must be made. Understandably, the assumptions presented by manufacturers and vendors are often biased to the desired result.

For our report, we shall assume that the fundamental engineering aspects of the site are the same for both types of tanks; that geotechnical parameters do not influence the selection; and that the service life is over 60 years with a full replacement at year-72. This is a reasonable and slightly conservative life-cycle. We shall also assume that the operational costs (cleaning, disinfection, sampling, etc.) for both types will be the same for a given size reservoir and may thus be removed from the analysis.

### COATING SYSTEMS

In this report, we shall assume that the interior and exterior coating systems (paints, epoxies, polyurethanes, etc.) are the same products with the same application costs. This is a balanced compromise in that we also assume the interior coating system is on the same cycle as the exterior coating system. In actual practice, the interior application is more sophisticated due to National Sanitary Foundation (NSF) and American Water Works Association (AWWA) water quality and potability requirements. The interior often is an Occupational Safety and Health (OSHA) confined space requiring specialized equipment and personnel. The interior environment is high humidity and must be dehumidified to properly apply new coatings with commensurate curing conditions. Also, it is often inaccessible except through roof hatches and scaffolding. Therefore, interior coating systems are often patched and re-coated in lieu of a complete removal and reapplication. This presents its own set of problematic variables in the coating system integrity but means the interior coating system life-cycle costs are probably lower than presented. Conversely, the exterior is readily accessible, by design, and the coating systems used are more common and easily applied. Matched with exterior exposure conditions, these coating system maintenance cycles are often less than 12 years which would correlate to increased life-cycle costs for this portion.

### RESERVOIR STRUCTURE GEOMETRY

We have also assumed a general geometric configuration for our tanks. In practice, they tend to be similar in height but have a variety of roof configurations from a full hemisphere on a WSP tank to an essentially flat roof for a PSC tank. As a compromise for surface area, we have averaged the application area of a hemisphere with that of a circle as a standard cover. Exceptions to this assumption are standpipes which by definition are taller than their diameter, are generally constructed of WSP, and frequently are 75 to 100 feet above grade from base to roof. Coating

maintenance for a standpipe can therefore be substantially higher than a comparable volume WSP reservoir.

## RESERVOIR MAINTENANCE

Industry maintenance practices are regionally specific. For example, the Mediterranean climate of San Diego differs markedly from the low humidity desert environment of Las Vegas and the humid rainy environment of Seattle. Coating systems in wet climes may have a shorter maintenance cycle than 12 years due to the ubiquitous moisture in the air and ground. This will push the cost of a steel tank up as compared to a PSC over the life of the facility. However, if the tank site is in a low-humidity desert environment, the coating system cycle may be the half-life of the facility. There is a plethora of variables that add and subtract from the actual costs and for the sake of brevity, this report presumes that these variables balance out in the environment of San Diego. Typical maintenance costs are at least double for a WSP versus a PSC facility of similar geometry. A summary of the coating system costs, which are the vast majority of all maintenance costs, is presented in Attachment 2.

Lastly, we have concurred with the interest and inflation rate analysis provided by a local PSC tank constructor, DYK, Incorporated (DYK). The general trend in inflation and interest rates is that they are equivalent values and reasonably low – in the 1-2% range. This simplifies the analysis and gives some preference to the higher operation & maintenance (O&M) costs associated with WSP tanks. It should be noted that a significant rise in either the interest rates or inflation rate, or both, will significantly impact the life-cycle cost by favoring the use of low maintenance-high capital cost construction practices, such as a PSC reservoir. A summary of the assumptions is presented in Attachment 2.

Attachment 1 illustrates the preference for WSP structures in the smaller volumes and PSC structures in the larger volumes. For a utility the size of the City of San Diego, the typical new reservoir volume is 3 to 10MG which concurs with the comparable cost region between WSP and PSC. Adjustment of maintenance practices (assumptions) will sway the decision towards PSC if the maintenance costs increase and towards WSP if they decrease.

Subtle features of each reservoir material or construction may influence the final decision. One such feature is in the AWWA testing requirements for WSP and PSC tanks. By definition, WSP tanks are completely sealed by full welds on all seams. AWWA Specification D 100-96 requires the acceptable leakage rate be zero for a new WSP reservoir installation. Conversely, AWWA Specification D 115-95 allows the acceptable leakage rate for a Class A tank to be less than 0.05% of the full tank volume over 96 hours. In a 3 MG facility, this could be 400 gallons per day. All new reservoir facilities are constructed with an underdrain water collection system to monitor for any seepage and often new PSC reservoirs meet the WSP requirement. An example of where this differentiation may be a factor is the placement of a recycled water storage facility adjacent to a potable water facility. Since the distribution of both water types is similar and requires the same siting conditions for storage facilities, it is anticipated that a hilltop could have both types of tanks. State of California Department of Health Services (CADHS) provides oversight in protecting the potable water distribution system. While there are currently no

regulations with respect to recycled water storage facilities, when compared to potable water, recycled water is often treated the same as wastewater to protect the potable water distribution system. This would favor constructing a WSP storage facility, for either one or both of the reservoirs, due to its zero seepage allowance if the facilities are co-located on a hilltop.

Physical characteristics of the two materials and their structural behavior come into play when making a site selection. In a perfect world, the desired location is at the necessary elevation that makes the high water line equivalent to the distribution system pressure in the zone served. Unfortunately, we have reality to temper our perfect world and many times have difficulty finding the perfect hilltop location. One method to place the tank at the proper height isn't often seen in San Diego: elevated storage tanks constructed to hold water at a desired system pressure (old University Heights). These facilities are more often found in areas with small topography differences in the service area. Standpipes are another type of elevated storage tank where instead of supporting the tank on legs, the tank extends all the way to the ground. In this scenario, the operational volume is only a fraction of the storage volume and the height is greater than the diameter. Elevated tanks and standpipes are almost exclusively WSP.

San Diego, however, is blessed with a varied topography which allows tank and reservoir placement not only on top of a hill but at a variety of locations from top to bottom. These sites often are partially buried for both structural and foundation stability reasons plus aesthetic reasons for the surrounding community. When considering a reservoir for such a site, PSC facilities are much more rigid and able to accommodate the buried condition. However, they also require a superior foundation with very little to no settlement allowed because they are unable to adjust to the moving ground condition. This often requires a larger developed footprint (surface area) to stay away from a cut/fill line on a sloped site and that may require significantly more land acquisition and grading. Alternatively, WSP is able to conform to significant settlement, in geotechnical terms, and still provide functionality because of its ductility; requires a smaller developed site footprint because it can tolerate a foundation made from "fill," and therefore less land to acquire and/or grade.

One last item to note is the impact of our seismic requirements on the selection of a reservoir. The AWWA standard that governs the design and construction of WSP storage facilities, D 100-96 is currently undergoing a significant revision. The lessons learned from the Northridge earthquake in 1994 are being incorporated into the design and construction standards for the water utility industry. As such, the pipe connections and how they behave during anticipated lateral and vertical movements of water storage facilities may affect the ultimate selection. As written previously, PSC is a very rigid, very stable structure which is not anticipated to move differently than the ground upon which it sits. If site conditions do not conform to uniform ground movement during a seismic event, WSP may be the preferred construction material for both the reservoir and the piping systems connected to it.

## CONCLUSION

Within the 1 to 5 MG capacity, WSP and PSC tanks compare favorably. During the investigation for this report, Water Department staff contacted several water agencies in the region of various

sizes. While they generally support the observations made in the report, they exhibited some agency bias towards one type of reservoir construction material in their distribution systems: they had either a preponderance of steel tanks or a preponderance of concrete tanks. We interpret this as the familiarity factor. The familiarity factor is exhibited in numerous unwritten policies where utility leaders (senior engineers, supervisors, managers, directors, etc.) are more familiar (comfortable) with a particular material, procedure, policy, engineering design, engineering design firm, etc. This bias is then communicated to the staff in an informal familiarization: if you only work on steel tanks you will tend to prefer steel tanks to the “unknown” concrete tanks. Supporting this bias, equipment for operation and maintenance is procured for the preferred type which tips the balance to incorporating more of the same type of facilities and equipment into the maintenance program. Decades of this practice result in systems having a preponderance of a single type of construction material. This familiarity is also seen in pipeline materials in both water and sewer systems. To the Water Department’s credit, there are a variety of tank types within the distribution system which develops a broader skill set for personnel maintaining the facilities. It also provides an opportunity to evaluate the effectiveness of each facility type in a reasonably controlled environment.

From the perspective of the Water Department, the selection of the tank material is dependent upon the specific site conditions, geotechnical parameters and meeting the distribution operating needs of the water system. A recommendation for using PSC reservoirs over WSP reservoirs cannot be made based on the capital cost alone. A thorough life-cycle analysis should be included during the Predesign or 10% Design Report. At this stage, the site conditions can be evaluated, the ultimate functionality addressed, specific assumptions about the future site compatibilities and maintenance schedules with respect to the proposed coating system(s) used, and the projected interest and inflation rates incorporated into the life-cycle cost analysis. The best-value selection for the Water Department can then be made. It can also be noted that most CIP projects involving reservoir and tank construction or rehabilitation also have a significant piping and appurtenance component that may be 50% or more of the total contract price. The incorporation of these appurtenant systems into the reservoir may also factor into the selection process.

Respectfully submitted,

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Water Department Director

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BELOCK/VB/OK/CM

Attachments:

1. Water Department Water Storage Facilities
2. Storage Facility Life-Cycle Cost Analysis
3. Welded Steel and Prestressed Concrete Reservoirs

# ATTACHMENT 1 – WATER DEPARTMENT WATER STORAGE FACILITIES

	NAME	SHAPE	TYPE**	CAPACITY (MG)
1	EARL THOMAS RESERVOIR	Cir	PSC	35
2	MIRAMAR 2	Rec	GUN	31.4
3	BLACK MOUNTAIN RESERVOIR	Rec	RC	25
4	ALVARADO EAST	Cir	PSC	21
5	ALVARADO WEST	Cir	PSC	21
6	MIRAMAR 1	Rec	GUN	20.8
7	SOUTH SAN DIEGO RESERVOIR	Rec	RC	15
8	UNIVERSITY HGTS RESERVOIR	Rec	RC	11.9
9	PT LOMA RESERVOIR	Rec	RC	10.9
10	RANCHO BERNARDO	Rec	RC	10.1
11	BAYVIEW RESERVOIR	Rec	RC	10
12	POMERADO PARK	Cir	WSP	5.2
13	PENASQUITOS	Cir	PSC	5
14	SAN CARLOS RESERVOIR	Cir	PSC	5
15	MIRAMAR RANCH NORTH RSVR	Cir	PSC	4.5
16	CARMEL MTN RANCH	Cir	PSC	3.2
17	SCRIPPS RANCH	Cir	PSC	3.2
18	PARADISE MESA	Cir	WSP	2.5
19	PACIFIC BEACH	Cir	RC	2.4
20	REDWOOD VILLAGE	Cir	WSP	2
21	CATALINA RESERVOIR	Cir	WSP	1.5
22	COLLEGE RANCH RESERVOIR	Cir	WSP	1.5
23	DEL CERRO RESERVOIR	Cir	RC	1.5
24	EMERALD HILLS	Cir	WSP	1.5
25	SOLEDAD RESERVOIR	Cir	RC	1.26
26	LA JOLLA EXCHANGE PL RSVR	Cir	RC	1
27	LA JOLLA VIEW STAND PIPE	Cir	WSP	0.7
28	LA JOLLA CNTRY CLUB RSVR	Rec	RC	0.5
** Reinforced Concrete (RC) Prestressed Concrete (PSC) Concrete Lined – Gunnite (GUN) Welded Steel Plate (WSP)				

## ATTACHMENT 2 – STORAGE FACILITY LIFE-CYCLE COST ANALYSIS

ATTACHMENT 2 – STORAGE FACILITY LIFE-CYCLE COST ANALYSIS											
Physical Parameters					Initial Cost			Maintenance Costs per 12-yr <sup>3</sup> cycle (nearest \$1,000)		Present Value (Nearest \$1,000)	
Size	Height (ft; typ)	Diameter (ft; typ)	Interior Surface Area (sq ft)	Exterior Surface Area (sq ft)	Steel <sup>1</sup>	Conc. <sup>2</sup>	Coating System Avg Cost/sq ft INT & EXT	Steel	Conc.	Steel	Prestressed Conc.
1MG	27	85	21396	15722	\$410,000	\$800,000	\$3.84	\$143,000	\$60,000	\$1,125,000	\$1,100,000
3MG	32	130	46252	32979	\$808,000	\$1,500,000	\$3.84	\$304,000	\$127,000	\$2,328,000	\$2,135,000
5MG	34	166	71837	50195	\$1,285,000	\$2,025,000	\$3.84	\$469,000	\$193,000	\$3,630,000	\$2,990,000
10MG	40	215	117780	81475	\$1,974,000	\$3,150,000	\$3.84	\$766,000	\$313,000	\$5,804,000	\$4,715,000

<sup>1</sup> Chicago Bridge & Iron (CBI)

<sup>2</sup> DYK Incorporated (DYK)

<sup>3</sup> Steel Plate Fabricators (SPF)

### Notes:

All costs are in US Dollars

No appurtenant items such as piping, pavement, disinfection, etc. are included in the tank cost

Assumes level site with no geotechnical difficulties

Roof surface area is the average between a hemisphere and a flat circle

Interior Surface Area is Wall + Floor + Roof (underside) Exterior Surface Area is Wall + Roof

Service life is 60+ years with full replacement in the 72nd year

Assume interior and exterior coating systems are the same

Water Operations exterior coats every 10 years; Mfg suggests 15: Use 12 year cycle

Interior coating same cycle as exterior for steel tanks.

Assume interest rate equals inflation rate

### ATTACHMENT 3 – Welded Steel and Prestressed Concrete Reservoirs



← 5 Million Gallon Welded Steel Tank  
(Pomerado Park Reservoir)



5 Million Gallon Prestressed Concrete Tank →  
(San Carlos Reservoir)